AD-A164 963 THE ROCKET EXHAUST EFFLUENT DIFFUSION MODEL(U) WEATHER SQUADRON (2D) PATRICK AFB FL DETACHMENT 11 C BOWAN 03 JUL 85 2WS/CP-85/006 1/1

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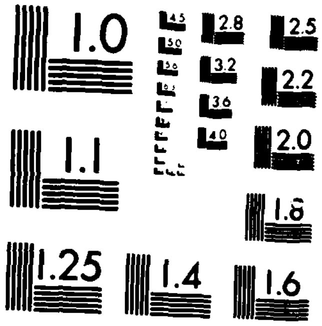

MICROCOPY RESOLUTION TEST CHART
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THE ROCKET EXHAUST EFFLUENT DIFFUSION MODEL (REEDM)

1. HISTORICAL DEVELOPMENT

The REEDM program has its roots in modeling efforts that go back more than 20 years. Beginning with a beryllium hazard study for the Pacific MIssile Range (PMR) in 1963 and continuing with the current effort to predict acid drop deposition from Shuttle operations in the relatively complex terrain at VAFB. As early as the late 1960's, it was recognized that existing point and volume source diffusion models were inadequate to handle the large spatial scales encountered in the launch of space vehicles. By 1970 the multilayer model had been formulated and implemented in a computer program to be used by NASA. One of the first uses of the model was the assessment of the Titan III D toxicity hazard at VAFB. The first version of the model was very primitive, requiring specification of stabilized cloud parameters and direct input of meteorological data. With time a preprocessor was developed which calculated the cloud height as a function of time, the stabilized source dimensions, turbulence parameters, and wind profiles. The model now included the capability to handle abnormal launches and had stored parameters to describe Titan, Delta-Thor, Minuteman, and Space Shuttle launches.

By the end of 1982 the REEDM program was operational at KSC and had supported launches of both the Titan and the Space Shuttle. A user's manual had been written and most program inputs were either selected according to the launch being supported or were available from information on file. A program execution could be run for HCl concentration calculations with every parameter defaulted except for the rawinsonde input file and the height of the mixing layer and be expected to produce correct answers.

At this time it was recognized that the fallout of acid drops from the ground cloud was a major problem; one that could not be addressed by the current version of REEDM. In 1983 and '84 algorithms to predict the deposition of the acid drops were developed and incorporated into the HP-1000 mini-computer version of REEDM.

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2. PROGRAM COMPONENTS

The REEDM program is logically divided into 5 parts: meteorological inputs, source inputs dependent on launch vehicle and type of launch, cloud-rise and material distribution algorithms, the dispersion model algorithms (there are three - - dosage/concentration, gravitational deposition, and washout deposition), and output routines.

2.1 Meteorological inputs

The program meteorological inputs all come from disk files resident on the same computer system as the program. During operational launch support the meteorological data is updated by other support programs which collect the data from rawinsonde ascents, tower data, and accoustic radar. Not all data sources are currently available at KSC. Although it is desireable to use all the sources of meteorological data listed above, the REEDM program has been developed to execute with only the rawinsonde in order to continue to provide output for hazard predictions. The capability at VAFB is increased by the addition of a mesoscale windfield model which will incorporate the influence of the complex terrain found there.

2.2 Source inputs

Source inputs are selected from stored values by the choice of launch vehicle and launch conditions and consist of trajectory data, heat emission data, and exhaust chemical constituents. These data affect the cloud-rise and total quantity of each reaction product used as input to the dispersion models.

2.3 Cloud rise and other vertical variable algorithms

The cloud rise algorithm is based on the work of Briggs and for normal launches uses his instantaneous cloud rise model. This model assumes that entrained air increases the radius of the ascending cloud as a linear function of the height gained since cloud formation. The REEDM program is a multi-layer model with the layer boundaries defined by the rawinsonde reporting levels entered in the data file. In order to reduce the error which would occur with excessively thick layers, the program will interpolate intermediate levels as needed. During incorporation of the acid drop deposition algorithm into REEDM, we found that limitations also had to be placed on the amount of directional shear within a layer. Once a satisfactory layering has been found by the program, the cloud rise algorithm computes the cloud height and vertical velocity as a function of time with output values at each layer boundary below the cloud stabilization height. The calculation of cloud vertical velocity is done on a layer-by- layer basis with the value of the stability parameter used in the cloud rise algorithm for each layer being computed from the average of the stability parameter through the vertical extent of the cloud (from the bottom of the cloud through the top of the cloud). The heat available for cloud rise through a layer is computed from the stored power law approximation to the launch vehicle ascent height vs time and the heat emission rate. The heat available is then the total heat output of the launch vehicle from engine ignition until the time the launch vehicle passes through the layer. The heat output has already been adjusted for the effects of radiation, after-burning, and the deluge water.

In the acid drop deposition model the vertical velocity used to carry the drops up into the cloud are computed assuming that there exists a parabolic velocity profile with a mean vertical velocity equal to the cloud rise velocity computed in each layer. The height to which drops are carried is computed by integrating the drop net velocity (local cloud vertical velocity minus the settling velocity for each drop size category) in time for as long as the net velocity is upward. This integration is performed for points at the center of the cloud and at the edge and defines the locus of heights reached by each drop size category. Drops are assumed to fall clear of the cloud when their net velocity becomes negative. Drops falling out in each layer are assigned to that layer as a source for the deposition model. Since the deposition model output depends upon the assumed drop size distribution and the only drop size distributions available were measured within the cloud at heights of 700 m, the initial (ground level) distribution was computed by using the cloud rise model and the drop source algorithm to match the distribution at the measured height of 700 m.

3. REEDM OUTPUT

Examples of REEDM output are shown in these last view-graphs where isopleths of acid drop deposition are shown on a maps of KSC and VAFB.

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ROCKET EXHAUST EFFLUENT DIFFUSION MODEL

(REEDM)

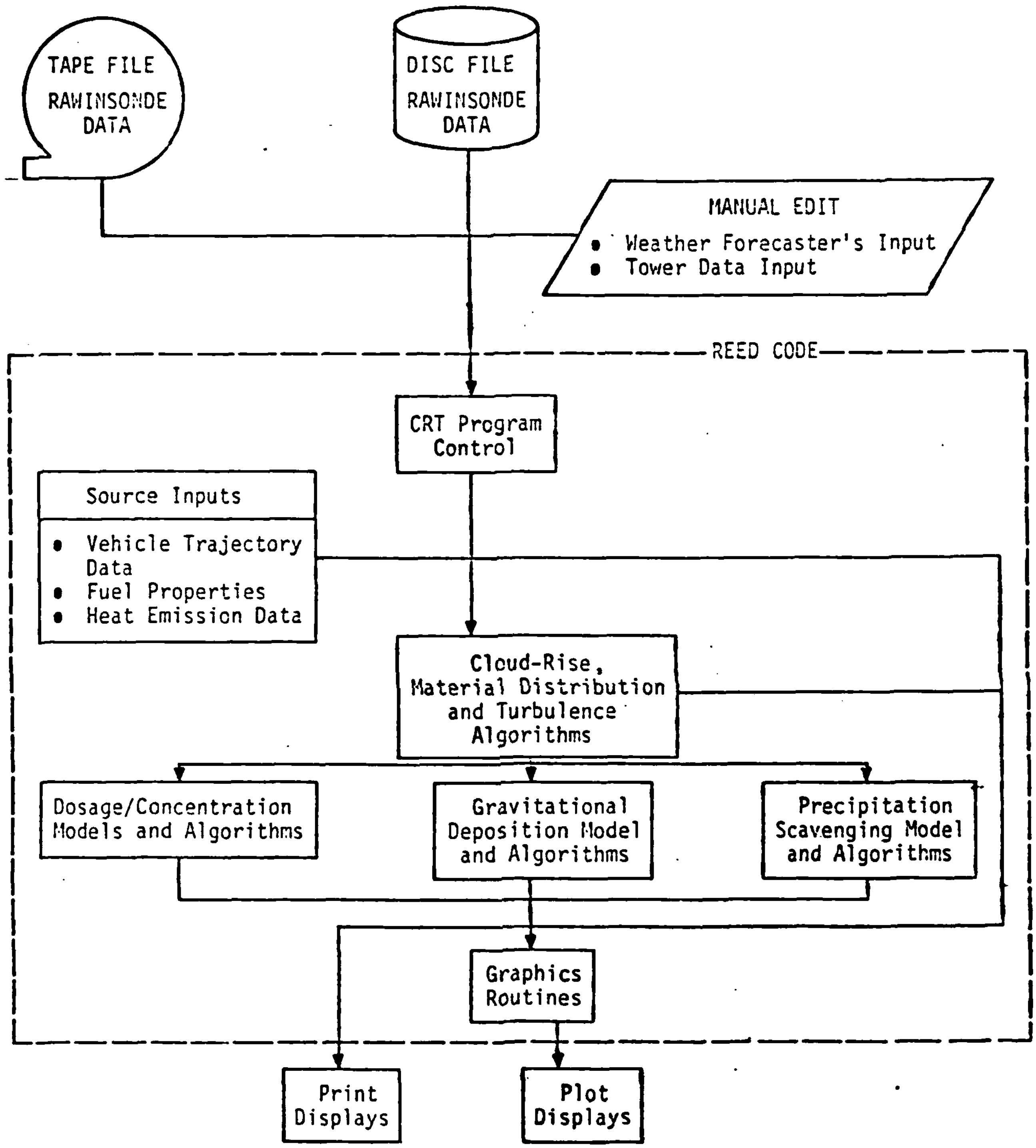

Figure 1. Schematic diagram illustrating major components of the REED structure.

```
RECORD                              CONTENTS
NUMBER                         (BEGINS IN COL. 1)
                         ------------------------

01. TEST NBR 09101  T MINUS 0          RAWIND  (VK1215)
02. RAWINSONDE RUN AN/GMD-1
03. CAPE CANAVERAL AFS, FLORIDA
04. 1515Z  12 NOV 1981
05. ASCENT NBR   0434
06.
07.
08.   ALT  DIR SPD  TEMP   DPT   PRESS  RH ABHUM DENSITY IR  VS   SHR  VPR  PW
09. GEOMFT DEG KTS DEG C DEG C   MBS   PCT  G/M3   G/M3   N KTS /SEC  MBS  MM
10.
11.
12.     16 310 015  22.4  16.0 1016.9 067 13.35 1190.4 345 672 .000 13.21  0
13.   1000 351 020  18.5  14.0 0982.2 075 11.89 1166.1 331 668 .022 12.20  3
14.   2000 004 019  15.2  13.0 0947.9 087 11.25 1138.5 322 664 .008 11.42  5
15.   3000 019 018  13.2  11.6 0914.4 090 10.36 1106.4 310 661 .008 10.91  8
16.   4000 016 016  12.2  -2.3 0881.9 039 04.18 1074.1 265 659 .003 10.48 10
17.   5000 004 014  11.7  -3.4 0850.4 035 03.64 1038.0 254 659 .006  9.62 13
18.   6000 351 010   9.5  -3.1 0819.9 041 03.73 1008.3 248 656 .007  8.27 15
19.   7000 358 010   7.4  -6.1 0790.2 038 03.07 0979.6 237 653 .002  4.67 16
20.   8000 006 012   6.0  -8.2 0761.5 035 02.56 0949.0 227 652 .005  1.76 17
21.   9000 000 015   6.4 -16.9 0733.7 018 01.34 0913.6 212 652 .006  1.76 17
22.  10000 354 017   5.6 -17.8 0707.0 017 01.17 0883.0 204 651 .004  1.60 18
23.  11000 346 017   4.6 -18.5 0681.1 017 01.10 0853.6 197 650 .004  2.39 18
24.  12000 337 018   3.1 -19.5 0656.1 017 01.02 0826.9 191 648 .005  2.22 19
25.  13000 333 020    .4 -21.2 0631.8 018 00.89 0804.0 185 645 .004  1.49 19
26.  14000 334 022  -2.1 -23.2 0608.2 018 00.75 0781.1 179 642 .004   .99 19
27.  15000 335 023  -3.9 -25.3 0585.3 017 00.63 0756.9 173 640 .001   .89 20
28.  16000 331 022  -6.7 -27.1 0563.1 018 00.54 0736.0 167 636 .002   .75 20
29.  17000 322 022  -9.4 -29.3 0541.5 018 00.44 0715.1 162 633 .006   .85 20
30.  18000 313 023 -12.1 -31.1 0520.5 019 00.37 0694.5 157 630 .006   .77 20
31.  19000 305 024 -15.1 -33.2 0500.1 019 00.31 0674.9 152 626 .006   .64 20
32.  20000 302 028 -17.0 -35.1 0480.3 019 00.26 0653.2 147 624 .007   .55 20
33. TERMINATION       88745 GEOPFT  27049 MTRS GEOP    18.5 MBS
34. TROPOPAUSE     48472   FEET    131.87 MB   -63.1 C    99.9 C    49N
```

FIGURE A-1. REEDM example run meteorological data file, taken from rawinsonde observation at Cape Kennedy, Florida 12 November 1981.

```
RECORD                            CONTENTS
NUMBER                        (BEGINS IN COL. 1)
                         ------------------------

35. MANDATORY LEVELS
36. GEOPFT DIR KTS  TEMP  D/PT PRESS   RH
37.
38.
39.    493 337 017  20.4  14.7 1000.0 070
40.   1936 003 019  15.4  13.1 0950.0 086
41.   3435 028 017  11.7  11.7 0900.0 100
42.   5005 004 013  11.6  -3.3 0850.0 035
43.   6658 352 010   7.8  -3.3 0800.0 045
44.   8396 006 014   5.7  -9.4 0750.0 034
45.  10248 352 017   5.3 -18.0 0700.0 017
46.  12224 335 018   2.3 -20.0 0650.0 017
47.  14324 334 022  -2.8 -24.0 0600.0 018
48.  16565 326 022  -8.4 -28.5 0550.0 018
49.  18960 305 024 -15.1 -33.2 0500.0 019
50. SIGNIFICANT LEVELS
51. GEOMFT DIR KTS  TEMP   DPT PRESS    IR  RH
52.
53.
54.     16 310 015  22.4  16.0 1016.90 345  67
55.   2235 008 019  14.4  12.5 0939.99 319  88
56.   3441 028 017  11.7  11.7 0899.98 308  90
57.   3718 018 016  12.2   2.2 0890.98 275  51
58.   4375 013 016  12.2  -8.2 0869.98 252  24
59.   6670 352 010   7.8  -3.3 0799.98 244  45
60.   7425 005 011   6.8  -9.7 0777.97 230  31
61.   8269 007 013   5.6  -7.6 0753.97 226  39
62.   9140 359 016   6.5 -18.7 0729.97 209  17
63.  11563 340 017   4.4 -18.8 0666.97 193  17
64.  19310 303 025 -16.0 -33.9 0493.90 151  19
65.
66, NNNN
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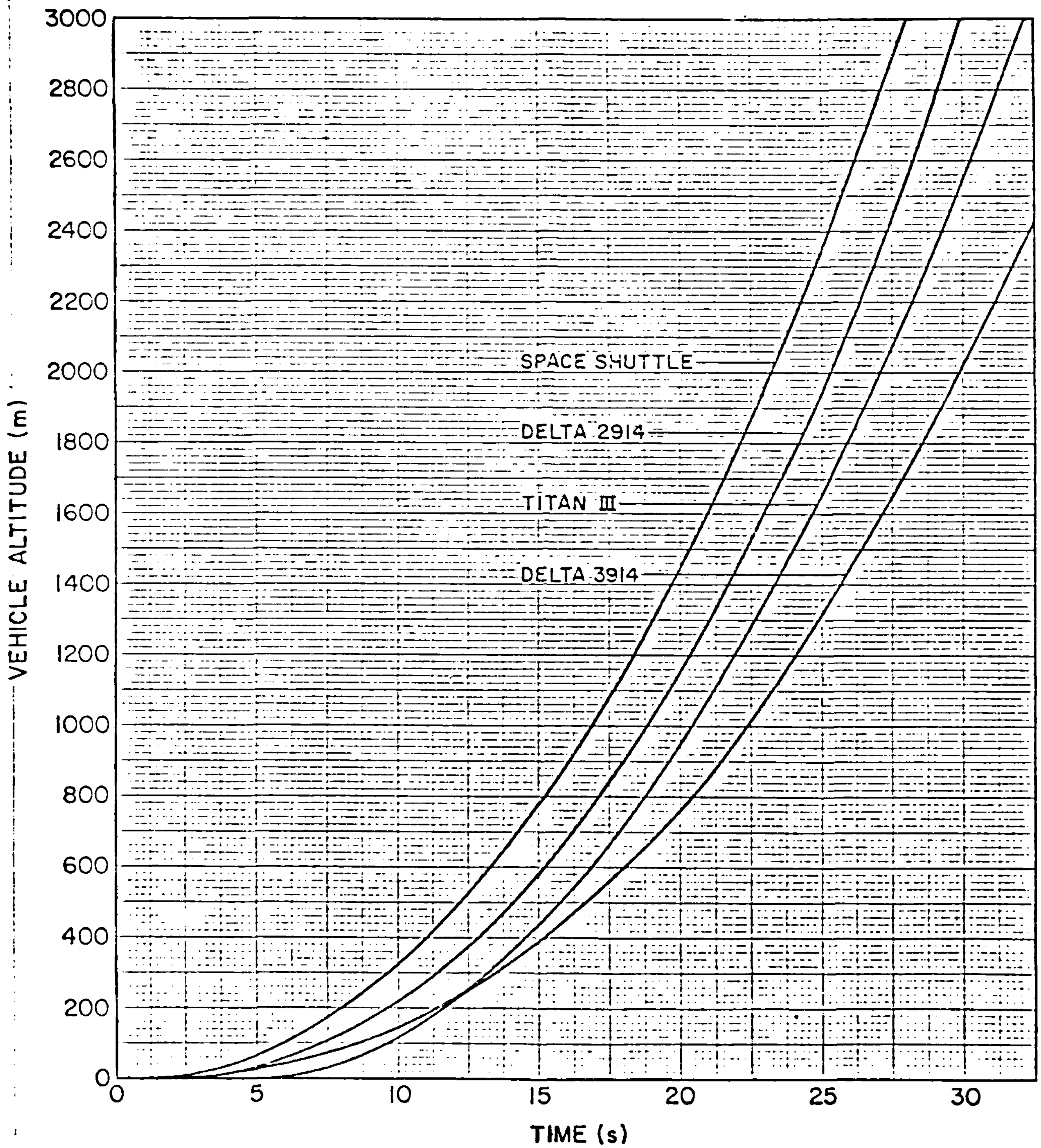
FIGURE A-1. (Continued)



Vehicle Altitude Versus Time

TABLE 2. FUEL EXPENDITURE AND HEAT CONTENT DATA

Property	Vehicle Type			
	Space Shuttle	Titan III	Delta 2914	Delta 3914
(a) Normal Launch				
Fuel Expenditure Rate W (g s^{-1})	1.5219×10^{7}	5.437×10^{6}	8.3607×10^{5}	1.0576×10^{6}
Effective Fuel Heat Content H (cal g^{-1})	1479.7	2021.1	1766.0	1449.9
(b) Launch Failure				
Fuel Expenditure Rate W (g s^{-1})	9.8873×10^{5}	1.3594×10^{6}	2.7294×10^{5}	3.7073×10^{5}
Effective Fuel Heat Content H (cal g^{-1})	1000.0	1000.0	690.0	411.2
Burn Time t_B (s)	1027.0	240.0	69.0	126.0

TABLE 3. VALUES OF THE CONSTANTS IN THE EXPRESSION FOR VEHICLE ALTITUDE VERSUS TIME

Vehicle Type	Constant		
	a	b	c
Space Shuttle	0.652213	0.468085	0.375
Titan III	0.429580	0.518422	5.0
Delta 2914	0.922156	0.432703	0.54
Delta 3914	1.245756	0.418095	0

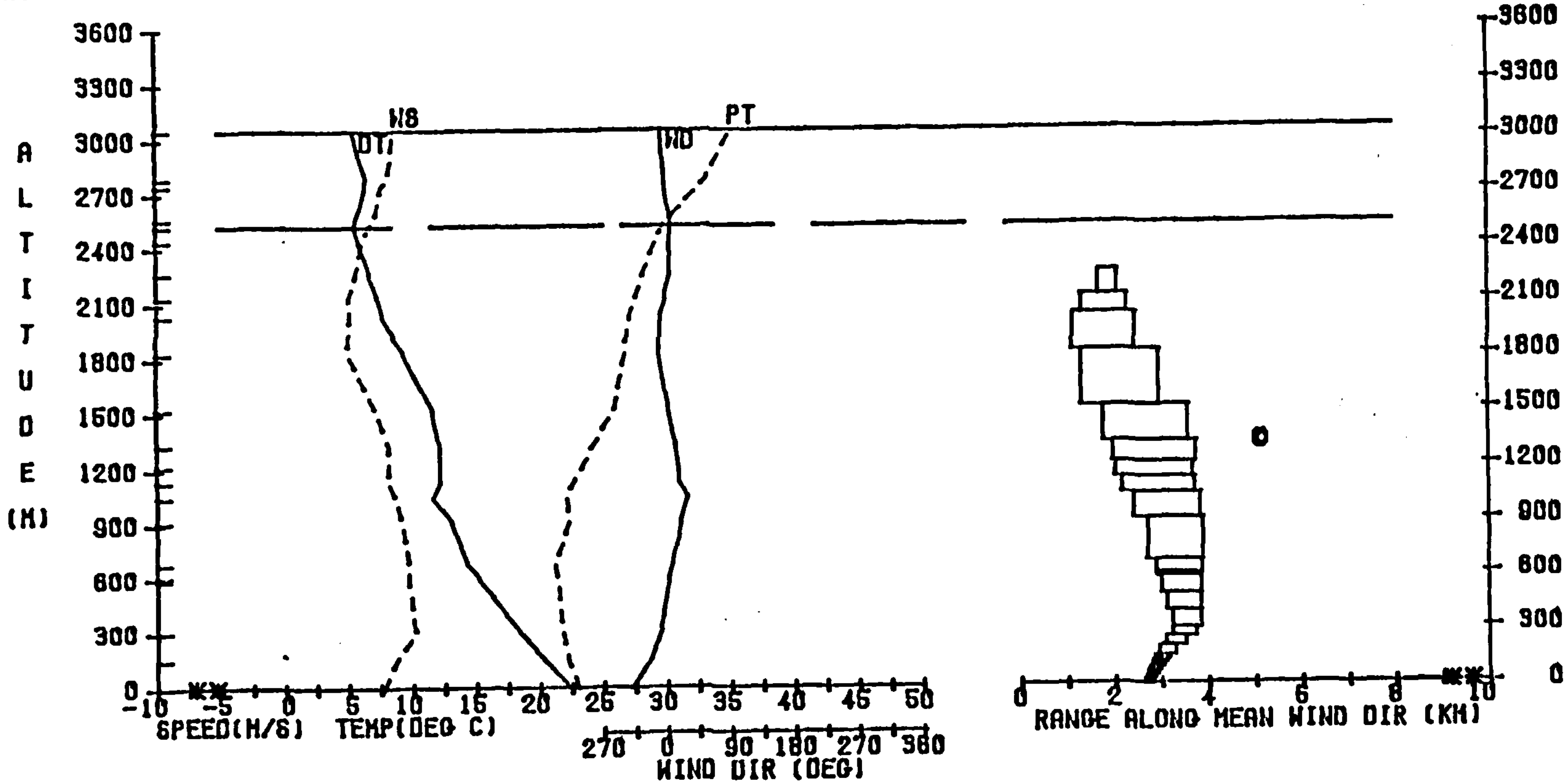
TABLE 4. EXHAUST CLOUD CONSTITUENTS (FRACTION BY WEIGHT)

Constituent	Vehicle Type			
	Space Shuttle	Titan III	Delta 2914	Delta 3914
$HC\ell$	0.0379	0.1932	0.1218	0.1589
$A\ell_2O_3$	0.1828	0.2819	0.2214	0.1936
CO_2	0.2503	0.2665	0.2055	0.2783
CO	0.00042	0.0222	0.0156	0.0331

DATE: 12 NOV 1981 TIME: 1015 EST PLOTTED AT: HEC FROM FILE: RAWIND

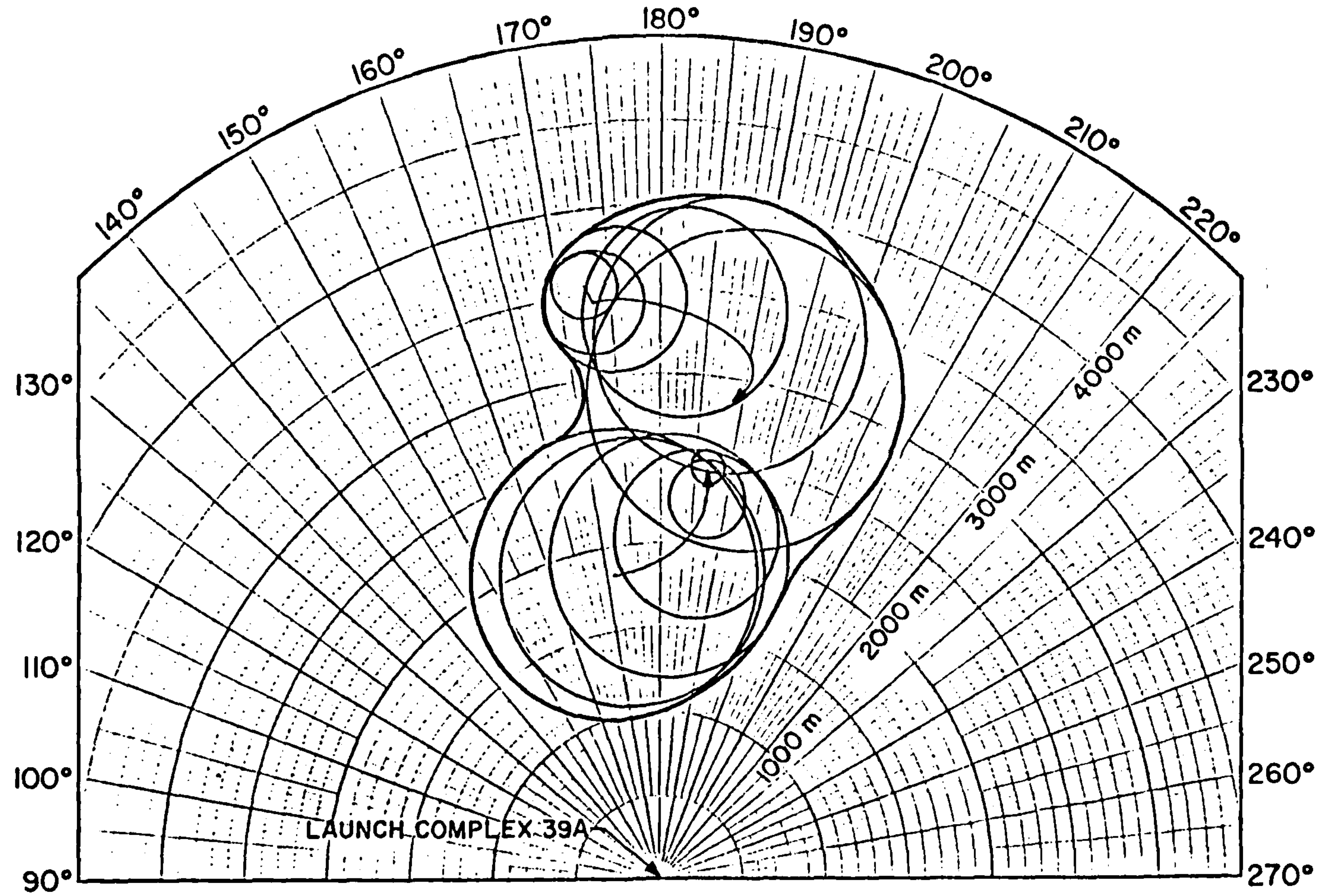
SURFACE PRESSURE: 1016.9MB DENSITY: 1190.4G/M3 o - STAB HT: 1315.7M ** - CALC HT: 0.0M

	LAYER1		LAYER2	
	SURFACE	TOP	BOT	TOP
ALTITUDE (M)	0.0	2520.4	2520.4	3048.0
DRY TEMP (DEG C)	22.4	5.6	5.6	6.6
POT TEMP (DEG C)	23.0	29.8	29.8	35.1
WIND SPEED (M/S)	7.7	6.7	6.7	0.7
WIND DIR (DEG)	310.0	7.0	7.0	354.0

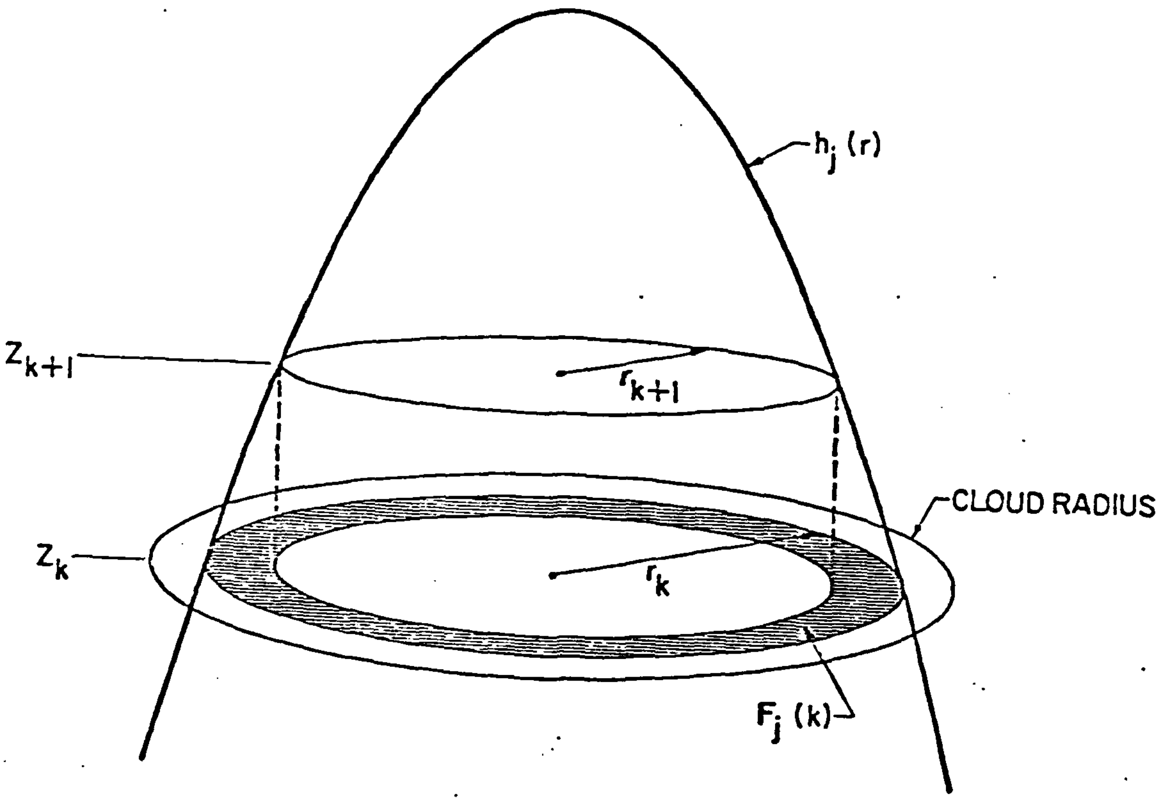


PLOTTED AT: *** 1126. 6 MAR 1985 ***

FIGURE 4: Meteorological profile plot produced by REEDM from KSC rawinsonde data for 0712 Eastern Standard Time, 12 April 1981.



Cloud Outline at Cloud Stabilization Time for STS-2



Fraction of Drops of the Jth Size Category Used as a Source in the Kth Layer in Acid Deposition Calculations.

$$F_j(K) = r_k^2 - r_{k+1}^2$$

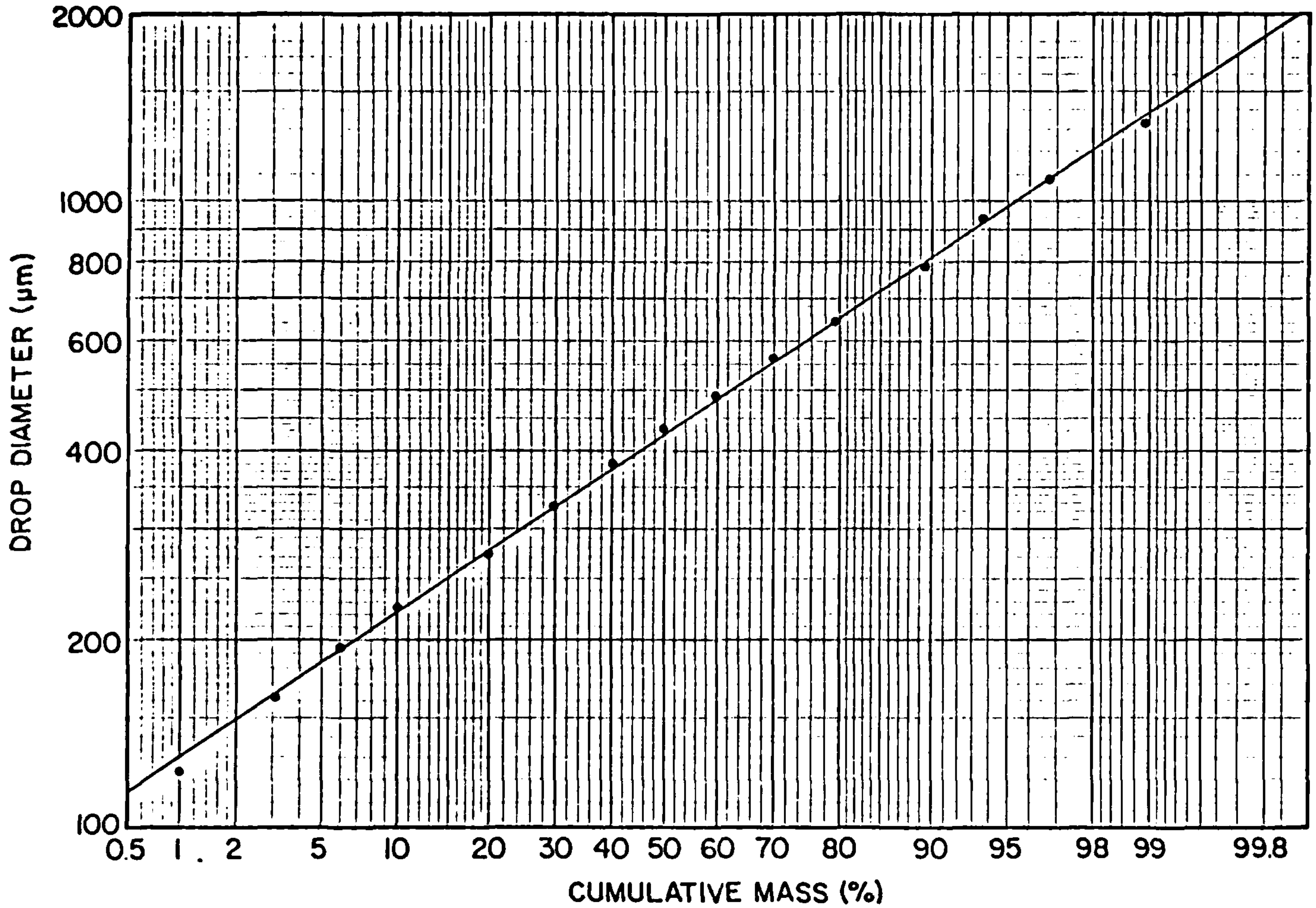


FIGURE 3. Cumulative mass distribution of acid drops based on the number distribution measured at an altitude of 700 m during STS-3 (solid line) and mass distributions predicted by the model at 700 m (dots).

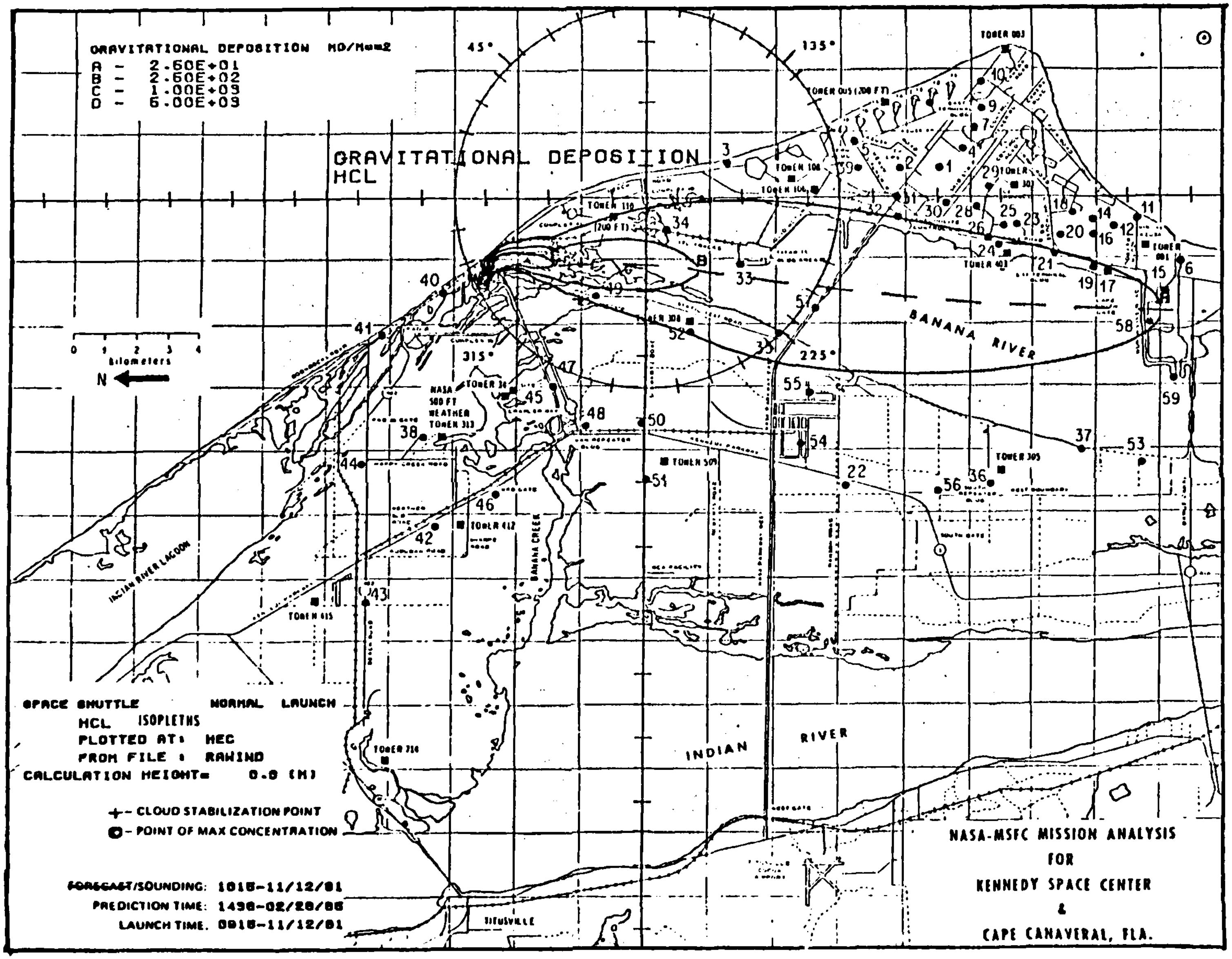


FIGURE A-11. Ground-level HCℓ gravitational deposition isopleth plot using the "LAND" map of Kennedy Space Center.

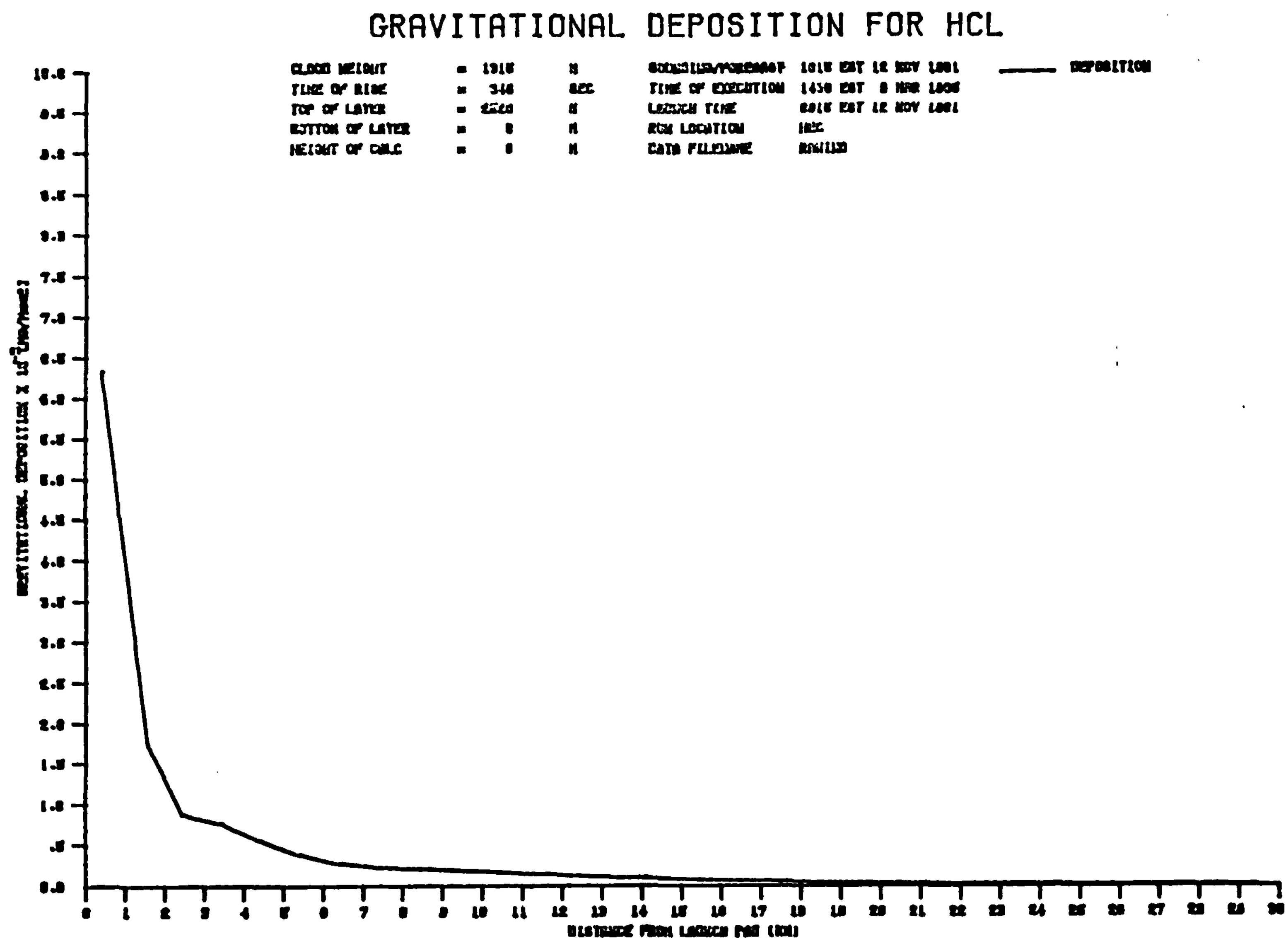


FIGURE A-10. Maximum centerline profile plot of ground-level gravitational deposition of HCℓ.

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